Pedobiologia 33, 113–116 (1989)
VEB Gustav Fischer Verlag Jena

[1])Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, and
[2])Department of Biology, New Mexico State University, Las Cruces, U.S.A.

Symphylella sp. (Symphyla: Scolopendrellidae) predators of arthropods and nematodes in grassland soils

DAVID EVANS WALTER[1]), JOHN C. MOORE[1]) and STEVEN J. LORING[2])

(Accepted: 88-10-26)

1. Introduction

In order to assess the importance of the fauna in soil processes, it is necessary not only to have accurate estimates of population density, biomass and energetics, but also to understand the function of individual species in the belowground system (MOORE *et al.*, 1988). The soil is a living material that is woven from the energy and nutrients that flow through the belowground food web. The pattern of this flow is determined by the resources used by the species that comprise the food web (MOORE & HUNT, 1988). Unfortunately, most of our assumptions about the trophic behaviors of the soil fauna have been made by analogy to a few well-studied taxa, often species considered to be of economic importance. As a result, incomplete or inaccurate assumptions about trophic function have become a serious hindrance to understanding the dynamics of the soil food web (WALTER, 1987; WALTER *et al.*, 1988; FRECKMAN, 1988).

A case in point are the Symphyla. The only symphylans with well-studied life histories are species of *Scutigerella* (Scutigerellidae), especially *S. immaculata* (NEWPORT), that often achieve high densities in cultivated soil (MICHELBACHER, 1949; EDWARDS, 1958), where they feed on living roots, decaying vegetation, microflora, and dead or dying symphylans (MICHELBACHER, 1938). In most general texts, Symphyla other than species of *Scutigerella*, have been assumed to function as detritivores feeding on decaying vegetable matter (e.g. WALLWORK, 1976; MANTON, 1977; SCHALLER *et al.*, 1968); it is a rare text that mentions the use of animal prey (KAESTNER, 1968). However, there are a number of reports of ingestion of arthropods by a variety of symphylans (MICHELBACHER, 1938, 1949; KAESTNER, 1968; ADIS & SCHELLER, 1984; LEETHAM & MILCHUNAS, 1985; WALTER *et al.*, 1988).

The purpose of this paper is to report on the gut contents of scolopendrellid symphylans (*Symphylella* sp.) that are common in grassland soils in the central United States, and to infer the appropriate trophic classification of these animals.

2. Materials and methods

Symphylans were recovered from plugs of sod taken to c. 15 cm (30 cm at Cheyenne) and extracted using Tullgren funnels or high-gradient extractors. Samples were extracted for up to 7 d, however, the relatively large and active symphylans typically appeared in extraction vials 1–3 d after being placed on funnels. Collections included: shortgrass prairie sod on the University of Nebraska Grassland Research Station near Sidney, Nebraska (Sidney, NE) and the Central Plains Experimental Range near Nunn, Colorado (CPER, CO); crested wheatgrass sod at the High Plains Grassland Research Station west of Cheyenne, Wyoming (Cheyenne, WO); low-elevation riparian grasslands in Hewlitt Gulch north of Poudre Park, Colorado (Hewlitt, CO), along the Colorado River west of Parachute, Colorado (Parachute, CO); a disturbed riparian site along the Cache la Poudre River south of La Porte, Colorado (La Porte, CO); and an abandoned alfalfa field in Fort Collins, Colorado (Ft. Collins, CO).

Symphylans killed in ethanol and mounted in Hoyer's medium were used for examination. Gut contents were observed under oil immersion (1,000 ×) on a Zeiss microscope. Examination began at the mouth, followed the esophagous until it entered the less well defined midgut behind the third pair of legs, and followed the midgut to the anal opening.

Identifications of arthropods were based on setae, solenidia, sensillae, legs, claws, chelicerae, mandibles, and integumental patterns on fragments found in guts. Nematodes were identified from stylets, buccal regions, and tail ends in guts. Fungal material was composed of short hyphal fragments and occasional spores. Specimens used in this study have been deposited in the Soil Arthropod Research Collection, Gillette Entomology Museum, Colorado State University, Fort Collins, CO.

Based on the presence of 9 pairs of coxal glands, 17 dorsal scuta without transverse belts of longitudinal striae, long cerci, vestigial legs I, and similar integumental sculpturing and setation, we believe that all of the symphylans observed belong to a single species in the genus *Symphylella* SILVESTRI (Scolopendrellidae). The collections from Sidney, NE have been erroneously reported to belong to the very similar genus *Symphelellina* (WALTER *et al.*, 1988).

3. Results

A summary of the gut contents of 106 field-collected symphylans are presented in table 1. Of these, 48 (45.3%) had no recognizable inclusions. Of the remaining 58 symphylans, 55 (94.8%) had the remains of up to 7 individual invertebrate bodies in their guts, and 3 (5.2%) animals had only fungal and/or apparent detrital material in their guts. Nematodes and arthropods represented most of the gut inclusions, and both types of prey were often present (sometimes filling the gut) in the same animal (19.0%). 21 animals (36.2%) contained some fungal as well as animal material in their guts. In 4 of these "omnivores", large muriform spores or simple conidia and hyphal fragments were observed as discrete gut contents, however, in most cases fungal material was intermixed with remains of an arthropod that ingests fungal material (e.g. collembolans and acarid mites), and it is likely that the fungal inclusions represented gut contents of devoured prey. 4 animals (6.9%) contained detritus-like material that appeared to represent decayed plant matter.

Table 1. Number of grassland soil symphylans (*Symphylella sp.*) containing different food types in gut contents. Individual animals often contained several types of prey.

Site (N)	Food Types					
	Nematoda	Arthropoda	Annelida	Fungi	Detritus	No Contents
Hewlitt Gulch, CO (N = 9)	1	3		2		6
Parachute, CO (N = 46)	11	18	1	6	1	22
La Porte, CO (N = 6)		1		1		5
Central Plains Experimental Range, CO (N = 8)	1	2				5
Sidney, NE (N = 9)	1	6		3	1	1
Fort Collins, CO (N = 20)	1	14		8	2	6
Cheyenne, WO (N = 8)	4	4		1		3
Total (N = 106)	**19**	**48**	**1**	**21**	4	**48**

Of the 58 symphylans with recognizable gut inclusions, 48 (82.8%) contained body parts of arthropods. Soft-bodied prostigmatid mites (Acari: Prostigmata) were identified in 19 animals (32.8%), and included species of Alicorhagiidae (*Alicorhagia*), Bimichaelidae (*?Alycus*), Rhagidiidae (*?Cocorhagidia*), Tetranychidae (Bryobiinae), and Pygmephoridae. 17 animals (29.3%) contained unidentified arthropod remains, probably belonging to mites and possibly to small beetle larvae. Collembola were identified in 11 guts (19.0%), symphylans (*Symphylella*) in 9 guts

(15.5 %), acarid mites (Acari: Astigmata, *Tyrophagus* sp.) in 4 guts (6.9 %), and the nymph of an oribatid mite (Acari: Oribatida) in a single gut.

Nematode remains were present in 19 gut contents (32.8 %). 10 symphylans from Hewlitt, Parachute, CPER, and Sidney contained large dorylaimid nematodes (Nematoda: Dorylaimida) with distinctive *Dorylaimus*-type odontostyles. Odontostyles resist digestion and free odontostyles were present in the posterior gut and near the anal opening in some symphylans after the nematode cuticle had been digested. However, one or more reserve odontostyles were often visible in intact dorylaimids, so it was not possible to accurately estimate the total number eaten. At least 7 individual dorylaimid bodies were present in the gut of a symphylan from the CPER, and at least 4 dorylaimids (+ 1 prostigmatid mite, 1 collembolan, and some fungal material) were found in a single symphylan gut at Hewlitt. Tylenchid and rhabditid nematodes were also tentatively identified in symphylan gut contents. A single symphylan collected along the Colorado River near Parachute, CO contained what appeared to be cuticle from a small annelid (?Enchytraeidae).

Attempts were made to observe feeding in living *Symphylella* in laboratory arenas following the procedures in WALTER *et al.*, (1988). These symphylans are large (adults 2,000−3,000 μm in length), active, and shun light. Powdered mushrooms, fungi, algae, nematodes, collembolans and prostigmatid mites were offered as prey, however, no feeding was observed and survival was poor. Symphylans were successfully maintained in the laboratory when provided with a layer of soil macroaggregates inoculated with collembolans (*Folsomia candida* WILLEM) and nematodes (*Acrobeloides* sp.), but symphylans hid among the aggregates and prevented observation of feeding behavior.

4. Discussion

Both nematode and arthropod remains were found in the guts of *Symphylella* sp. in 6 of 7 sites sampled. In the seventh site, La Porte, 5 of the 6 animals examined had no identifiable contents. These sites included: native shortgrass prairie (CPER, Sidney); native (Parachute, Hewlitt) and disturbed (La Porte) riparian grasslands; and disturbed prairie (Cheyenne, Ft. Collins). Gut contents included predators (rhagidiid mites, alicorhagiid mites, and symphylans), fungivores (collembolans, acarid mites, pygmephorid mites, and nematodes), and herbivores (tetranychid mites and probably nematodes), as well as fungal and detrital material. 45 % of the symphylans had no recognizable gut contents. There are several possible explanations for an apparently empty gut. Animals may have recently voided their guts in preparation for a molt, feeding may be cyclic or seasonal, or recent hunting may not have been successful. Nematode prey are very difficult to observe in gut contents, and it is likely that predation on nematodes has been underestimated in this study (WALTER, 1988).

Unlike *Hanseniella arborea* SCHELLER which has gut contents packed with fungi and some arthropod fragments (ADIS & SCHELLER, 1984), *Symphylella* sp. has primarily animal remains in its guts. If *Symphylella* sp. were to be considered detritivores or scavengers, the traditional functional role assigned to symphylans, then one would have to assume that *Symphylella* sp. search out dead soil invertebrates, and occasionally augment their diet with fungal material or plant detritus. Symphylan remains were found in the guts of 9 *Symphylella* sp., and it seems plausible that these remains could have resulted from scavenging of exuvia or weakened (dying or molting) individuals, since herbivorous symphylans such as *Scutigerella immaculata* have been reported to feed on dead and dying conspecifics (MICHELBACHER, 1938, 1949). However, it seems an unnecessary intellectual contortion to assume that relatively large, active animals with strong, heavily-sclerotized mandibles, such as *Symphylella* sp., cruise through the soil looking for the much smaller bodies of dead nematodes, mites, and springtails. We suggest that, based on gut contents, *Symphylella* sp. should be considered top predators or, more accurately, top omnivores in grassland soils in the central United States.

5. Acknowledgements

We would like to thank two anonymous reviewers for their comments. This work was supported in part by NSF Grant BSR-8418049.

6. References

ADIS, J., & U. SCHELLER, 1984. On the natural history and ecology of *Hanseniella arborea* (Myriapoda, Symphyla, Scutigerellidae), a migrating symphylan from an Amazonian black-water inundation forest. Pedobiologia **27**, 35–41.

EDWARDS, C. A., 1958. The ecology of Symphyla. Part I. Populations. Ent. Exp. & Appl. **1**, 308–319.

FRECKMAN, D. W., 1988. Bacterivorous nematodes and organic matter decomposition. Agri. Eco. Environ. **24**, 195–218.

KAESTNER, A., 1968. Invertebrate zoology. Volume II. Interscience Publ., N.Y. (H.W. and L. R. Levi, translators).

LEETHAM, J. W., & D.G. MILCHUNAS, 1985. The composition and distribution of soil microarthropods in the shortgrass steppe in relation to soil water, root biomass, and grazing by cattle. Pedobiologia **28**, 311–325.

MANTON, S. M., 1977. The Arthropoda. Habits, functional morphology, and evolution. Clarendon Press, Oxford, 527 pp.

MICHELBACHER, A. E., 1938. The biology of the garden centipede *Scutigerella*. Hilgardia **11**, 55–148.

– 1949. The ecology of Symphyla. Pan Pacific Entomol. **25**, 1–11.

MOORE, J.C., & H. W. HUNT, 1988. Resource compartmentation and the stability of real ecosystems. Nature **333**, 261–263.

– D. E. WALTER, & H. W. HUNT, 1988. Arthropod regulation of micro- and mesobiota in belowground detrital food webs. Ann. rev. Ent. **33**, 419–439.

SCHALLER, F., 1968. Soil animals. Univ. Michigan Press, Ann Arbor.

WALLWORK, J. A., 1976. The distribution and diversity of soil fauna. Academic Press, N.Y., 355 pp.

WALTER, D. E., 1987. Trophic behavior of "mycophagous" microarthropods. Ecology **68**, 226–229.

– 1988. Predation and mycophagy by endostigmatid mites (Acariformes: Prostigmata). Exp. Appl. Acarol. **4**, 159–166.

– H. W. HUNT, & E. T. ELLIOTT, 1988. Guilds or functional groups? An analysis of predatory arthropods from a shortgrass steppe soil. Pedobiologia **31**, 247–260.

Synopsis: *Original scientific paper*

WALTER, E. W., J. C. MOORE & ST. J. LORING, 1989. *Symphylella* sp. (Symphyla: Scolopendrellidae) predators of arthropods and nematodes in grassland soils. Pedobiologia **33**, 113–116.

Inspection of the gut contents of 106 symphylans (*Symphylella* sp.) collected from 7 grassland sites in the central United States revealed that, of the 58 animals with food inclusions, 94.8% had been feeding on animal prey. Most gut contents were comprised of soft-bodied arthropods (prostigmatid, acarid, and nymphal oribatid mites, collembolans, and symphylans) and nematodes. Fungal material was a minor component of gut contents, typically single spores or small packets of fungal material with the remains of mycophagous arthropods (collembolans and mites). Detrital material was identified in only 4 animals. Although symphylans are usually considered to function as detritivores or root-feeders, these findings suggest that species of *Symphylella* function as omnivorous predators in grassland soils in the central United States.

Key words: Scolopendrellidae, Symphyla, *Symphylella*, predators, omnivore, Arthropoda, Nematod, gut content

Address of the corresponding author: DAVID EVANS WALTER, U.S.D.A., A.R.S., S.P.P. Unit, Horticultural Research Laboratory, 2120 Camden Road, Orlando, FL 32803, U.S.A.